

FOREST SOIL MITES AND MINERAL CYCLING

BY

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ABSTRACT

Mites and other small arthropods in forest soil exert an influence on the forest ecosystem in several ways. Their feeding processes cause a physical breakdown of fallen leaf litter, and the material passed through their intestines is more susceptible to decay by microorganisms. Fragments of leaf litter become more intimately mixed with mineral soil and are distributed vertically by the feeding activities and vertical migrations of soil mites. The impact of these activities on maintenance of the forest may be assessed by measuring quantities which reflect the functioning of the entire ecological system. Rates of cycling of minerals from tree through litter and soil and back to tree constitute one of the functional measurements which can now be made conveniently by the use of radio active tracer techniques.

In experiments at the Oak Ridge National Laboratory, leaf litter was confined in small (1 dm²) net bags and placed on the forest floors of pine, oak, and tulip poplar stands. Gross loss of weight and of radioactive isotopes of cesium, ruthenium, strontium, and cobalt was then measured at weekly intervals; simultaneously, the succession of soil mites in the bags was followed so that the loss of weight and of minerals could be related to arthropod activities. In other experiments naphthalene was used to exclude mites and other arthropods from experimental plots (1 m²). Comparisons with control plots showed that, after 1 year, plots without arthropods retained 55 % of their leaf litter (by weight) whereas control plots retained 40 %. Retention of radioactive cesium by leaf litter was changed also. Plots without arthropods retained 16 % of their initial cesium content, as compared to 7.5 % in control plots.

INTRODUCTION

In numbers alone, mites are the dominant arthropods in forest soils. Berlese funnel extraction techniques easily reveal mite populations of approximately 10⁵-10⁶ individuals per m² of forest floor, although technical questions on the various

1. Speaker.

2. Operated by Union Carbide Corporation for the U. S. Atomic Energy Commission.

Acarologia, fasc. h. s. 1964. (C. R. I^{er} Congrès Int. d'Acarologie, Fort Collins, Col., U.S.A., 1963).

extraction procedures make the precision of these estimates questionable (MURPHY, 1962). Increasing numbers of ecological studies on soil mites are being done, with the general objectives of interpreting these vast numbers of individuals in terms of their significance to the development and maintenance of forest floor systems. Life histories, food habits, and activities of soil mites have not been investigated adequately. Nevertheless, studies which attempt to relate forest soil mites to the other biota and to substrates of the forest floor are beginning to demonstrate the importance of the soil mites.

In general mites may be said to contribute to the over-all fertility level of forest soils. To some extent they feed directly on leaf litter, twigs, and other organic matter which falls from the forest canopy and so contribute to a physical breakdown of these materials. Decomposing materials are mixed intimately with mineral soil through mite activities, and chemical changes occur which enhance decomposition by microflora. Also mites are vectors of the microflora which are active in the decomposition processes. Vertical and horizontal movements of the mite populations tends to redistribute the organic materials in the forest floor. The burrowing activities of the mites may contribute to channeling and aeration of the soil, although larger invertebrates are probably more effective in these processes. The impact of these activities on the forest ecosystem, and their contribution to the maintenance of that system, may be assessed by measuring attributes which affect the functioning of the system as a whole. Two such functional aspects which are being used to characterize ecosystems are energy flow (MACFADYDEN, 1963) and mineral cycling (OVINGTON, 1962).

Materials accumulated from soil by trees, and accumulated energy, serve as a food base for the community of herbivores and predaceous animals. Similarly, the unconsumed organic material, the droppings of the animals, and eventually the bodies of the animals themselves serve as a base for a second food chain on the forest floor. It is in this degradation of dead organic matter that soil mites produce both direct and indirect influences. Estimations of the loss of weight, decline in energy content, and loss of mineral elements from decaying leaf litter, all seem promising as means for estimating the over-all influence and importance of soil mite populations. The combination of radioactive tracer techniques with conventional methods is providing new means for measuring these functional aspects.

LITTER BAGS AND RADIOISOTOPES

Recently, several workers have used litter bags (Fig. 1) to measure leaf litter decomposition rates, release of radioisotopes, and associated soil arthropod and microbial populations. With this technique, leaf litter is weighed, counted for radioactivity, enclosed in fine mesh bags, and placed on the forest floor. At later intervals bags are collected for reweighing, counting for radioactivity, extraction of arthropods, and estimates of microbial activity. In this manner simultaneous

estimates may be made of physio-chemical and biological phenomena. To supplement the brief account of litter bag procedures given here, the reader is referred to BOCK and GILBERT (1957), SHANKS and OLSON (1961), and WITKAMP and OLSON (1963) on measurements of weight loss; EDWARDS and HEATH (1963), and CROSSLEY and HOGLUND (1962) on arthropod populations in litter bags; WITKAMP (1963) on microbial measurements; and OLSON and CROSSLEY (1963) on loss of radioisotopes from litter bags.

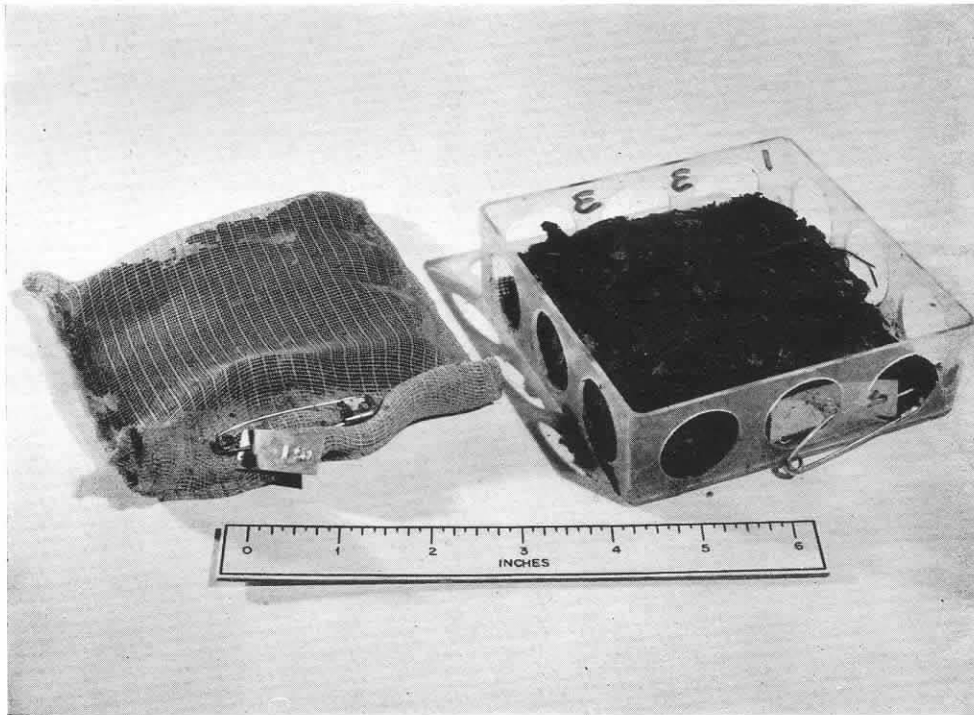


FIG. 1. — Litter bag and substrate box. Left, fiberglass bag (1 dm²) containing oak leaf litter, secured with safety pin and numbered with metal tag. Right, plastic box containing slab of forest floor. Note openings in sides of box to provide free entry to soil fauna. Bottom of box closed with plastic screening material.

One of the advantages of litter bag and similar techniques is the possibility for experimental designs using combinations of stand, leaf species, substrate, altitude, mesh size, and other factors. In this way the effects of these factors on the forest floor community can be identified and isolated. For example, an experiment was performed to isolate the effects of stand type and leaf species upon soil mite communities. Figure 2 illustrates weight loss by bagged leaf litter placed in pine and oak stands for this experiment. Fiberglass bags 1 dm² and with a 1 mm mesh were filled with pine (*Pinus virginiana* Mill.), oak (*Quercus falcata* Michx.), or dogwood (*Cornus florida* L.) leaves, and were placed in the field stations in

November, following the peak of annual leaf drop. One bag of each leaf species from each stand (total 6 bags) was collected and returned to the laboratory each week, weighed, Berlesed, counted for radioactivity, and then returned to the field site. Repeated measurements were made on the bags at 8-week intervals. Each leaf — stand comparison showed a similar gross pattern of weight loss: a rapid initial rate presumably due to loss of water-soluble materials, a slow rate during the remainder of the winter, and an accelerated rate during spring and summer.

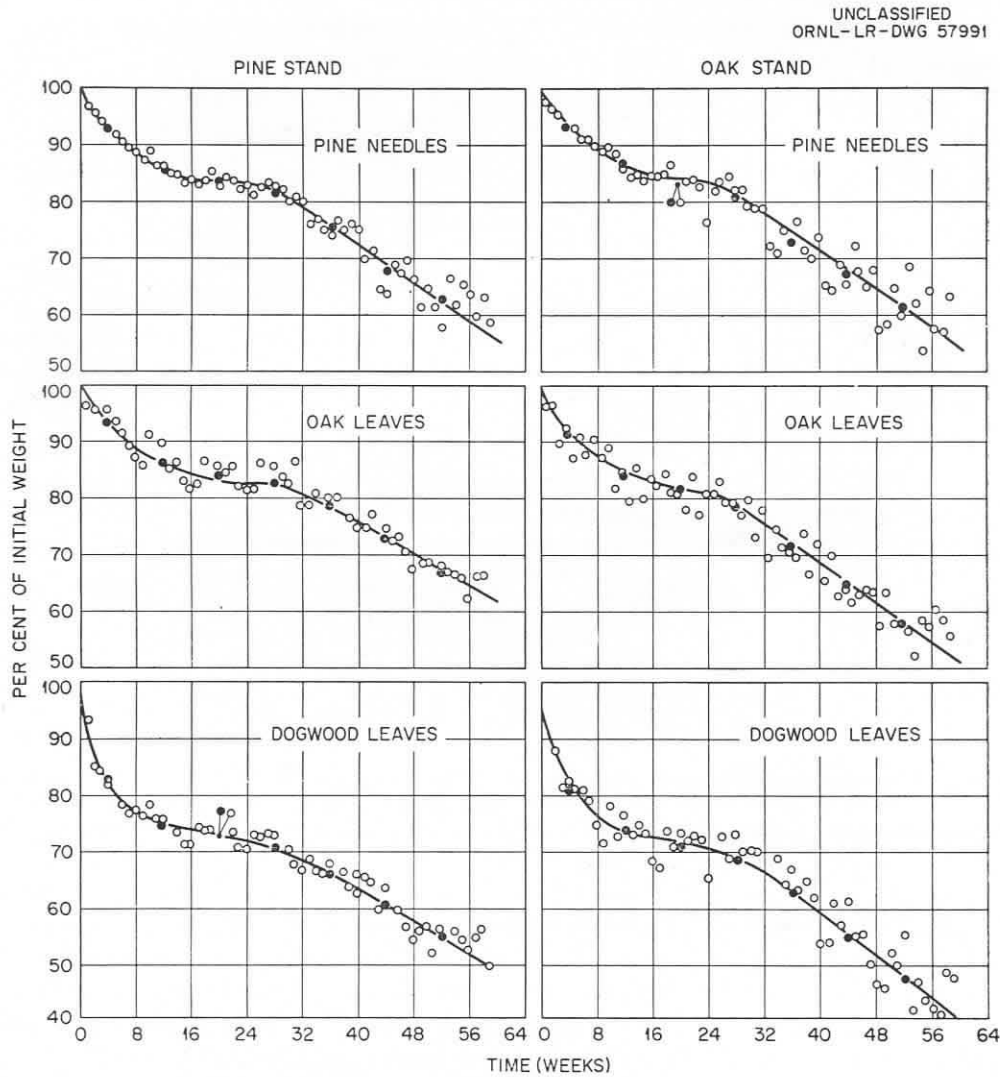


FIG. 2. — Weights of decaying leaves in litter bags, expressed as a percentage of initial weight of litter, through time. Three leaf species in two stands. Hollow circles are individual measurements; solid circles are averages for eight-week cycles. Lines fitted by eye. (after OLSON and CROSSLEY, 1963).

Figure 2 illustrates more rapid weight loss in the oak stand than in the pine stand, for each of the three leaf species. Dogwood leaves decayed more rapidly than did pine or oak. Radioisotopes in these materials (Ru^{106} in pine, Ru^{106} and Co^{60} in oak, and Sr^{85} in dogwood) were released at rates similar to losses of weight. Cesium-137, however, was lost more rapidly than was weight.

Analyses of soil mite populations revealed by Berlese extractions of litter bags show that the development of mite populations in freshly fallen leaf litter is analogous to the phenomenon of ecological succession. Initially only a few species invaded the bags but they were represented by large numbers of individuals (several hundred per bag). As litter decomposition proceeded an increased number of species invaded the litter bags but they developed smaller populations than did the initial invaders. Species diversity reached a maximum in September and October. These results differ from those obtained with the conventional techniques of core sampling, since cores usually contain litter in all stages of decay as well as mineral soil. Berlese extractions of cores thus contain mites associated with various stages of decomposition, but with litter bags it is possible to follow one portion of leaf litter as it decays, and to observe succession of mite species.

The experimental design was chosen to permit evaluation of leaf species versus stand type as factors affecting the occurrence of mite species. If food preferences by mite populations were strong, then each leaf species might have its own characteristic fauna regardless of type of stand. In this experiment the type of stand (oak or pine) proved a more important factor than leaf species, however. Different mite species populations were sometimes found for the three leaf species at any one sampling interval, but the differences were due in part to decay stage of the leaf species. An additional modification for this type of experiment would include the interchange of slabs of forest floor between stands, in addition to exchanges of leaf litter. Figure 1 illustrates a plastic sandwich box modified to support a slab of substrate beneath a litter bag.

GROSS EFFECTS OF ARTHROPODS AND MICROFLORA ON RATES OF LEAF LITTER BREAKDOWN

The processes of leaf litter breakdown and decay are the result of a complex interaction between soil animals, including mites, and soil microflora. A gross estimate may be made of the influence of animals on the breakdown process, by excluding them from experimental areas and then measuring litter breakdown caused by microflora alone. In our experiments naphthalene was used to suppress animal populations. Weight loss and radiocesium loss from bagged leaf litter were used as criteria for evaluation of litter decomposition. Of course, the results are applicable to the entire soil fauna and not to the mites alone. The experiments were conducted in a hardwood stand (predominantly oak) with a mor soil, in which larger arthropods were not numerous.

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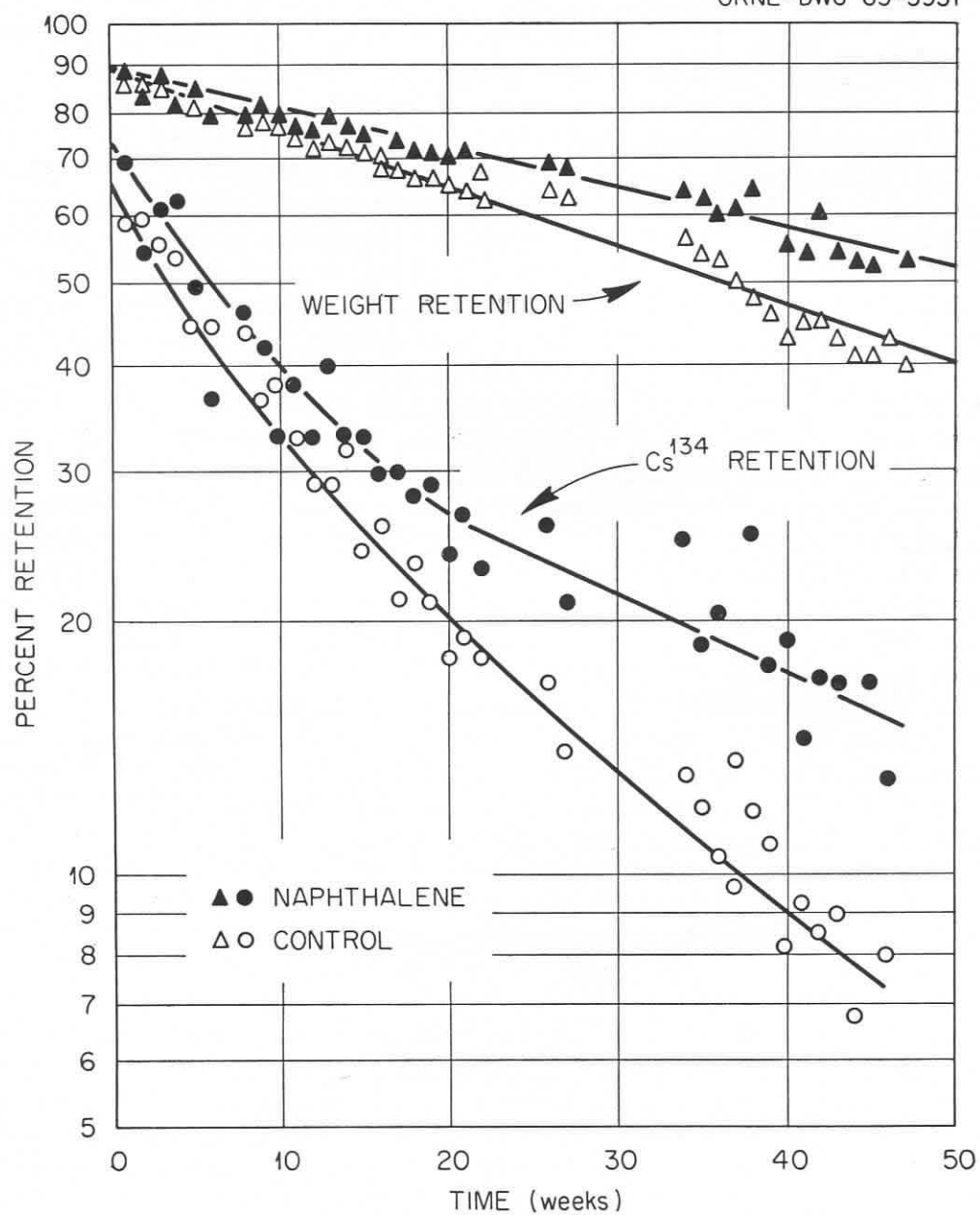


FIG. 3. — Weight retention and Cs^{134} retention by bagged leaf litter, in control plots and in plots receiving 100 g of naphthalene per m^2 of forest floor. Lines fitted by eye.

After a preliminary screening experiment naphthalene was selected as the insecticide for use, primarily because it produced fewer effects on soil microflora than did paradichlorobenzene, dieldrin, or chlordane. KURCHEVA (1960) also used naphthalene in a similar experiment, and reported that decomposition caused by bacteria and fungi continued to occur in the presence of naphthalene.

In the experimental procedure twelve 1-m² plots of oak leaf litter received levels of 100, 35, 10, or 0 g of naphthalene (3 replicates $\times$ 4 treatments). Weekly measurements on litter bags provided data on weight loss, Cs¹³⁴ loss, and numbers of arthropods. Biweekly measurements were made of soil plus litter respiration and microflora. It was necessary to reapply naphthalene at about 4-week intervals during the winter and at weekly intervals during the summer. Arthropod populations in the 100-g naphthalene plots averaged about an order of magnitude below populations in the control plots.

Figure 3 illustrates both weight loss and radiocesium loss from litter bags in plots receiving 100 g naphthalene per m² and in control plots. After 50 weeks in the field, control litter retained 40 % of the initial weight; litter treated with naphthalene retained 55 % of the initial weight. Cesium-134 loss rates showed a difference even more striking. Percentages of Cs¹³⁴ retained by bagged leaf litter in naphthalene treated plots and in control plots were 16 % and 7.5 %, respectively, showing that radiocesium loss rates were cut in half by exclusion of soil fauna. Plots receiving 35 or 10 n naphthalene were intermediate in weight and Cs¹³⁴ loss rates. These trends were confirmed by measurements of weight and radiocesium losses for individual bags, for bags left undisturbed for the entire year, and for weights of total forest floor remaining in the twelve plots.

The difference in radiocesium loss rates from control and experimental plots is greater than would be expected from change in weight alone. Litter treated with naphthalene not only retained more weight but retained more cesium per unit weight as well. A probable explanation is that the activities of the soil fauna tend to fragment the litter and thus expose a greater surface to the leaching action of rainwater. It appears, then, that the activities of the soil fauna are effective in promoting the release of stored minerals from leaf litter, above and beyond their feeding activities.

Data obtained in this experiment are only relative, since arthropods were not completely eliminated from the naphthalene treated plots. The experiment shows, however, that the effect of the soil fauna on weight loss and mineral loss from leaf litter is of major importance. KURCHEVA (1960) performed a similar experiment and achieved even more dramatic results. Oak litter treated with naphthalene lost only 9 % of its original weight, whereas litter without naphthalene lost 55 % during a 140 day experiment. These data were obtained for a variety of oak (*Quercus robur* L.) which retains its leaves until spring. Probably, then, the readily soluble materials had already leached out when the experiment was started in the spring. Litter without soil fauna thus lost little weight.

CONCLUSIONS

The experiments described in this paper are related to attempts to quantify the importance of soil mites (and other elements of the soil fauna) to the maintenance of the forest ecosystem. New techniques in such studies — radioisotopes, litter bags, use of insecticides, and other experimental approaches — can provide a fresh insight into the ecological problems confronting the acarologist who studies soil mites. Such experimentation is best approached from a functional viewpoint; that is, an over-all consideration of the ecosystem as a unit, and the soil mites as a part of that unit. Information on the structure of mites communities may also be obtained from these types of experiments, however. Our studies demonstrate that the soil fauna produces marked effects on such ecosystem properties as mineral cycling, measured by radioisotope release from leaf litter in the absence of an abundant soil fauna. The detailed study of the mite communities which develop in litter bags can lead to a new understanding of the functioning of this community, when weight loss and mineral loss from leaf litter are measured simultaneously with mite populations. The combination of disciplines necessary for the interpretation of such studies suggests that a joint effort by acarologists, microbiologists, foresters, ecologists, and others, will be a most productive approach. Still, the myriad of problems concerning the activities of soil mite populations under field conditions are sufficient to warrant the attention of the individual investigator in the Acarina.

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